# On coating of separator electrodes.

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**FNAL/TD**

## **FNAL separators.**

We want to increase operating voltage in some of the 22 separators from

46 kV/cm (230 kV total voltage across gap)
to
63 kV/cm (312 kV total voltage across gap)

and keep very low sparking rate.

# Some existing machines

## KEK

Electrodes
300x40 cm

Cathode
Anodized Al

Anod
Stainless steel

Gap 10 cm

Up to 900 kV
(Gas He 70% +
30% Ne, 0.07 Pa)

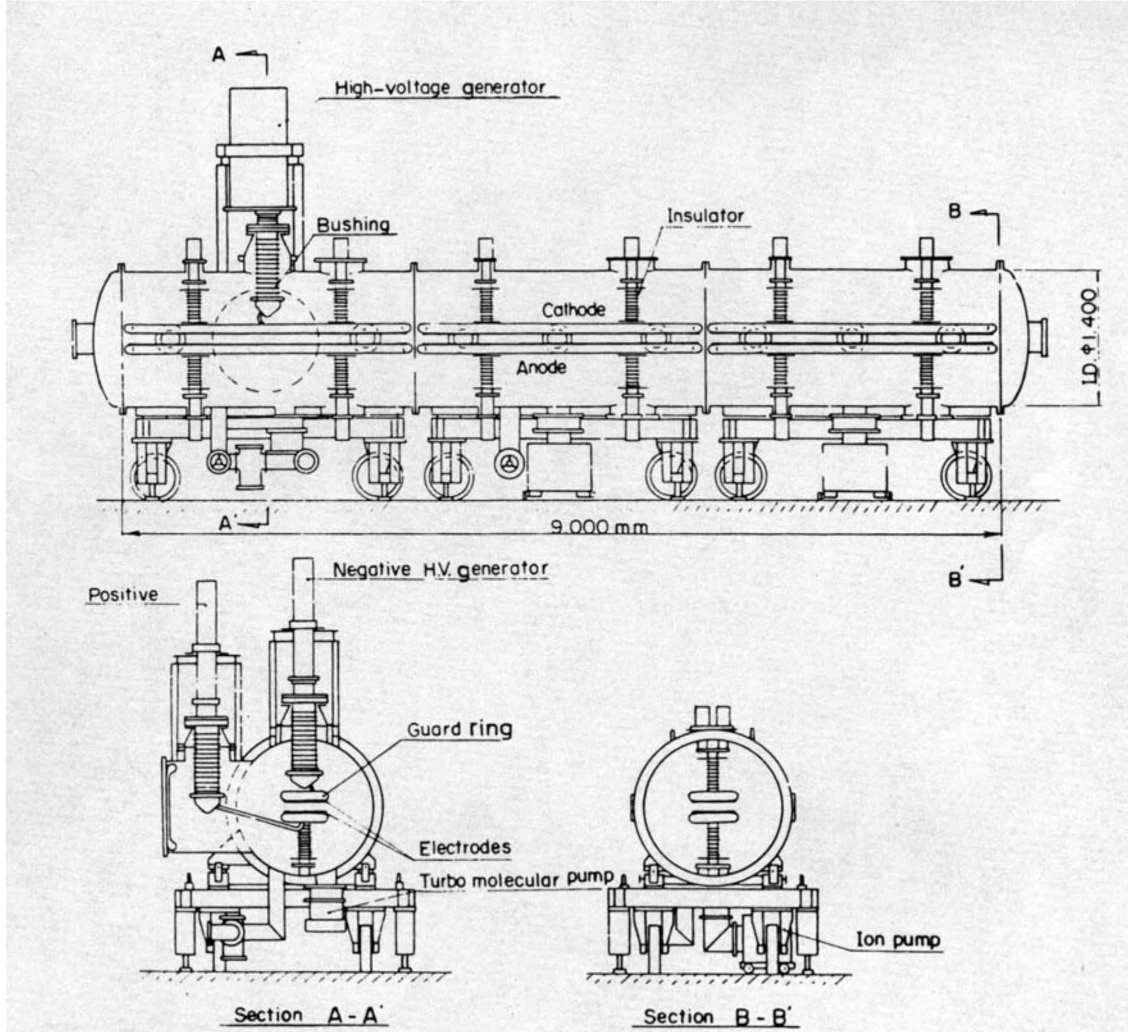


Fig. 3. Schematic view of the 9 m separator.

## Some existing machines

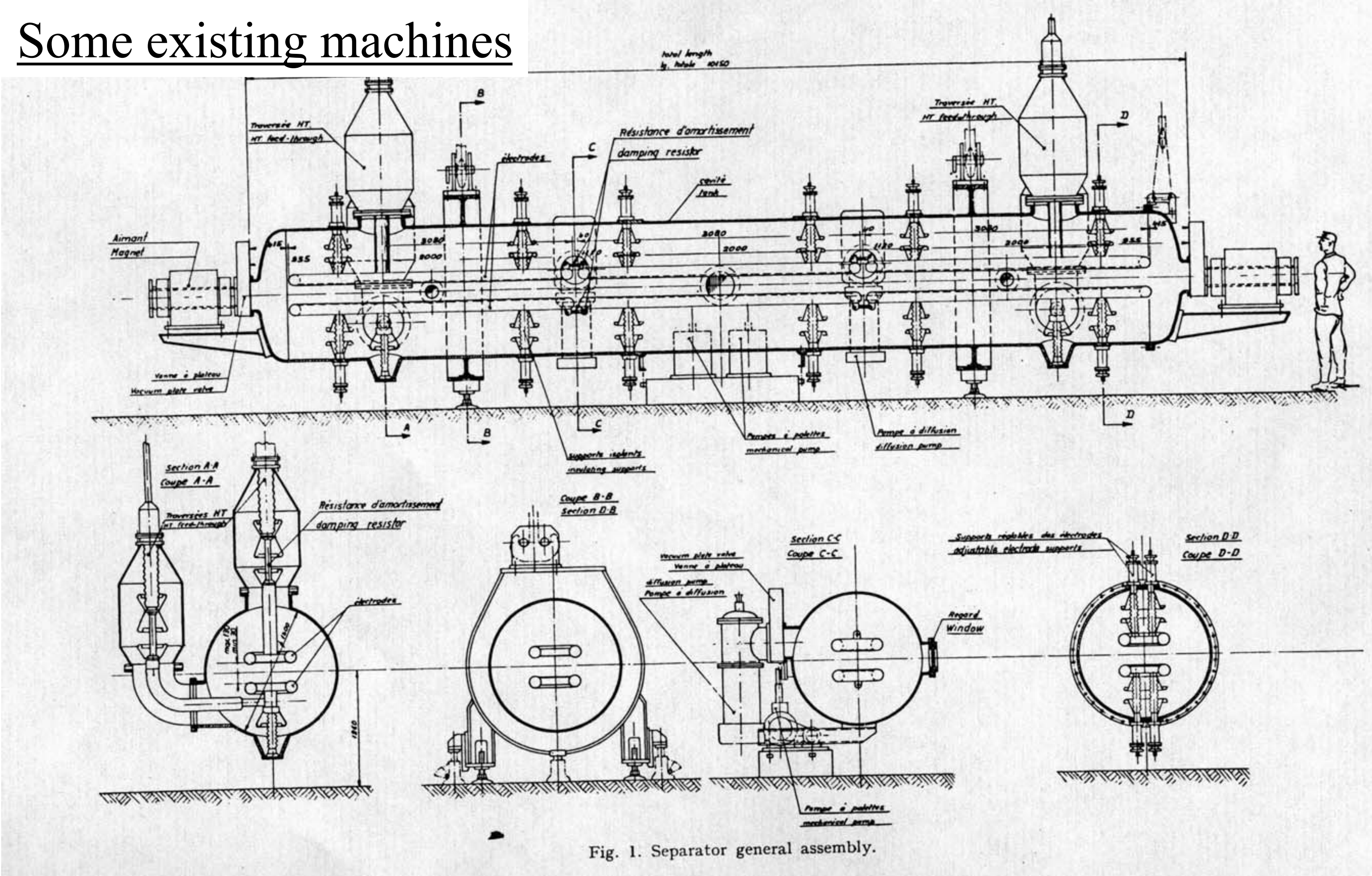



Fig. 1. Separator general assembly.

CERN. Electrodes 300x55 cm. Cathode - Anodized Al, Anod - Stainless steel.
Gap – 6-26 cm (adjustable). 800 kV (for d = 8 cm). Gas – 0.05 Pa.

# Some existing machines

Electrodes 15X460 cm
Pure titanium
Gap 8 cm
Operating voltage 240 kV
Operating field 30 kV/m
16 tanks

ELECTROSTATIC BEAM SEPARATION SYSTEM
OF TRISTAN MAIN RING

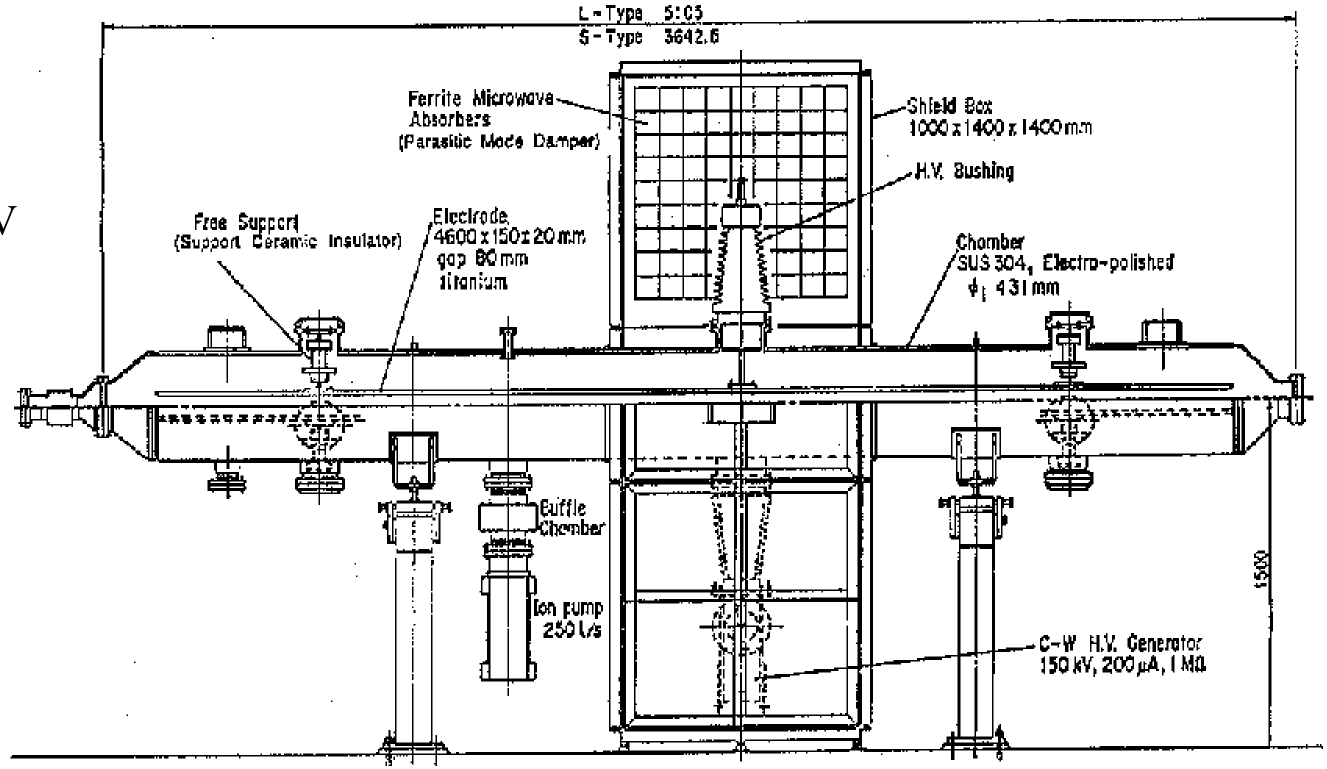



Fig.2 Separator chamber.

# Some existing machines

Inner diameter 540 mm
Electrodes 4m x 260 mm (Stainless steel)
Gap 60-160 mm (adjustable)
Nominal field strength – 20 kV/cm
Nominal voltage 220 kV
32 tanks

CERN, LEP

1186

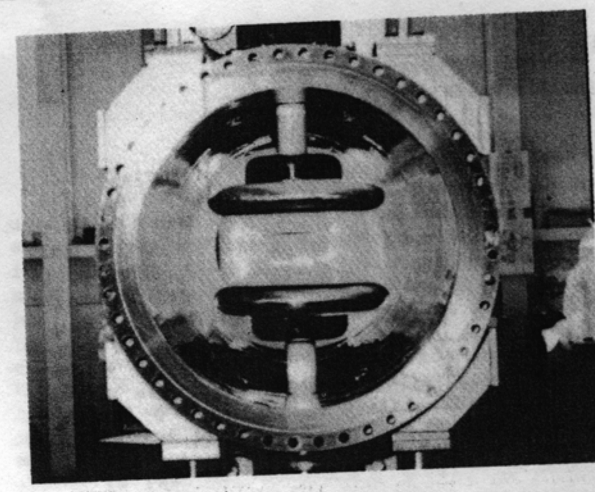
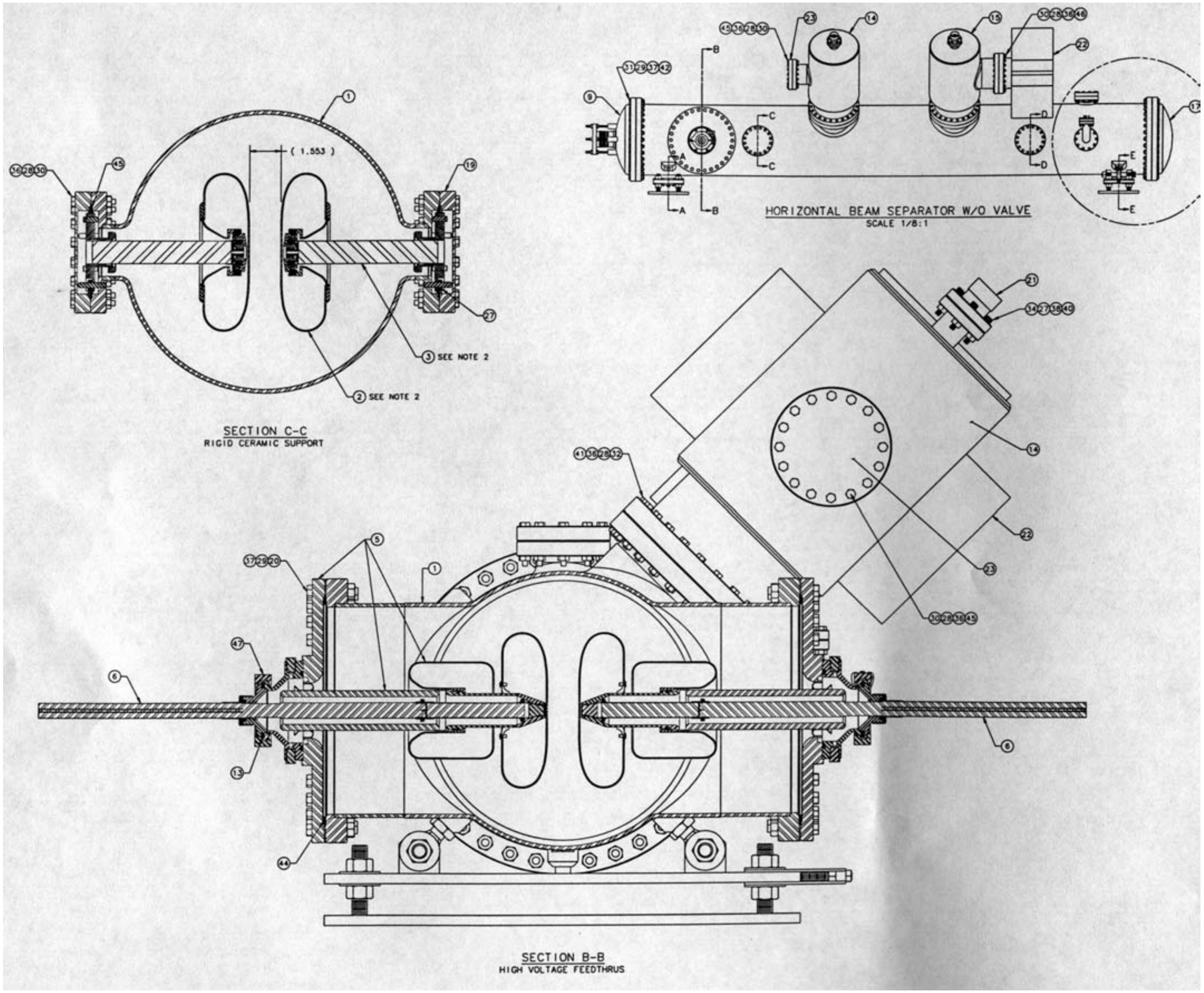


Fig. 5: Cross-section of a separator with electrodes and metal-ceramic supports.

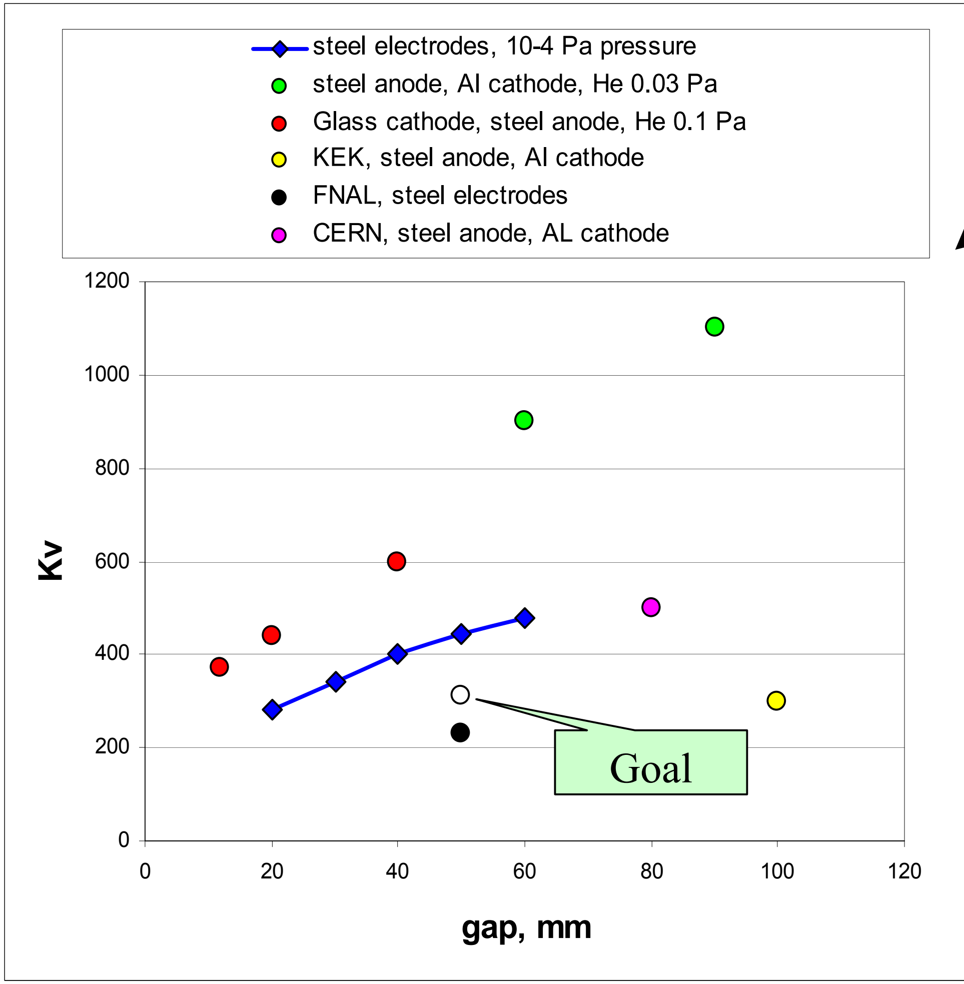
significant thermal bending of the electrode. Through ... of an internal structure consisting



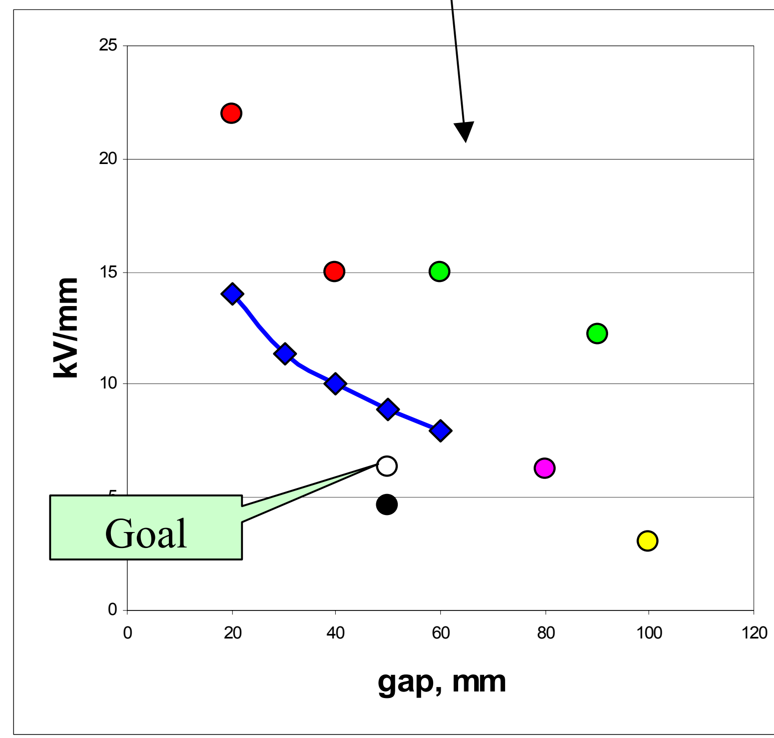

<u>FNAL separator.</u> Stainless steel electrodes 20x257 cm, gap – 5 cm.

# Comparison of high voltage records

Total voltage




Field strength




It seems that there is a room for improvement, but…

# Comparison of separator operating voltages

Big gaps, big surfaces, low sparking rates make difference.

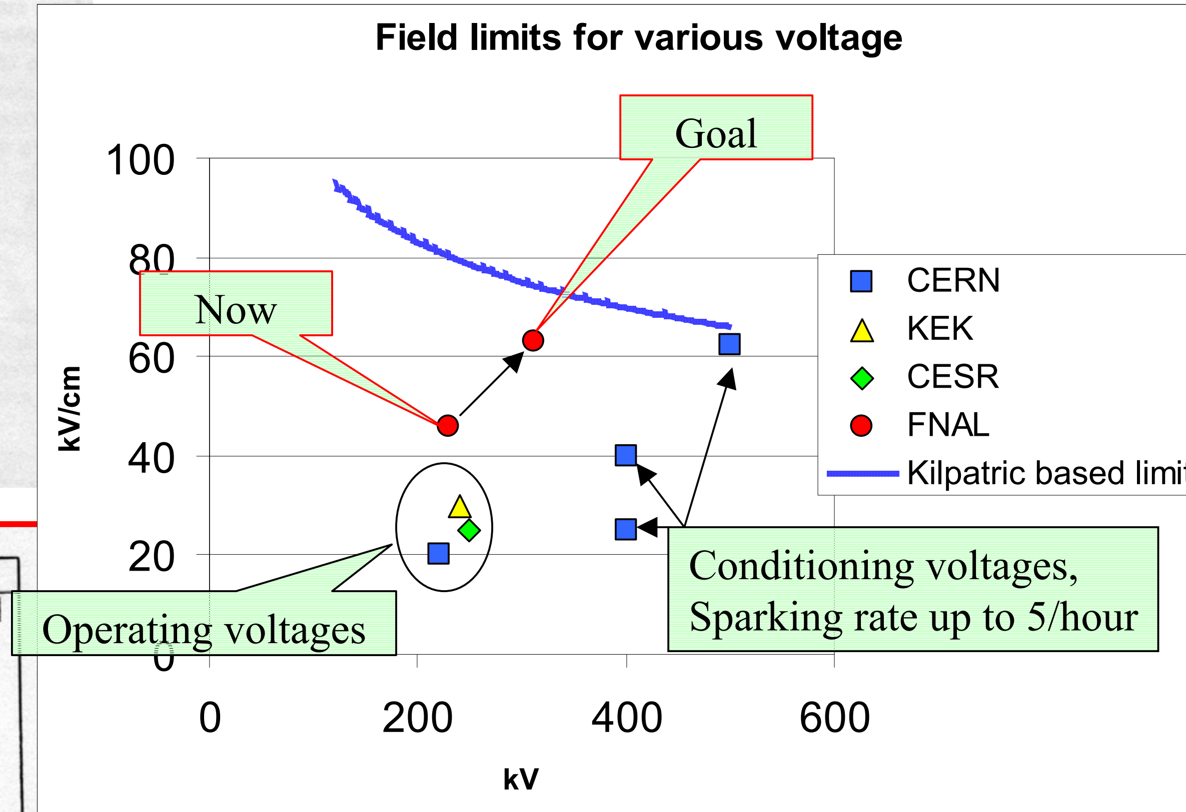
Table 1: The "maximum operating field" is the maximum operating gap voltage divided by the gap width. Processing voltages and fields are higher. Gaps at CERN are variable from 60 to 160 mm.

| Site | Operating Field Max. [kV/cm] | Operating Gap Voltage Max. [kV] |
|---|---|---|
| CERN [2] | 25 | 400 |
| KEK | 30 | 240 |
| CESR | 25 | 250 |
| FNAL | 50 | 250 |

Table 2: Field limits for various voltages based Kilpatrick criterion for typical separator voltages [6].

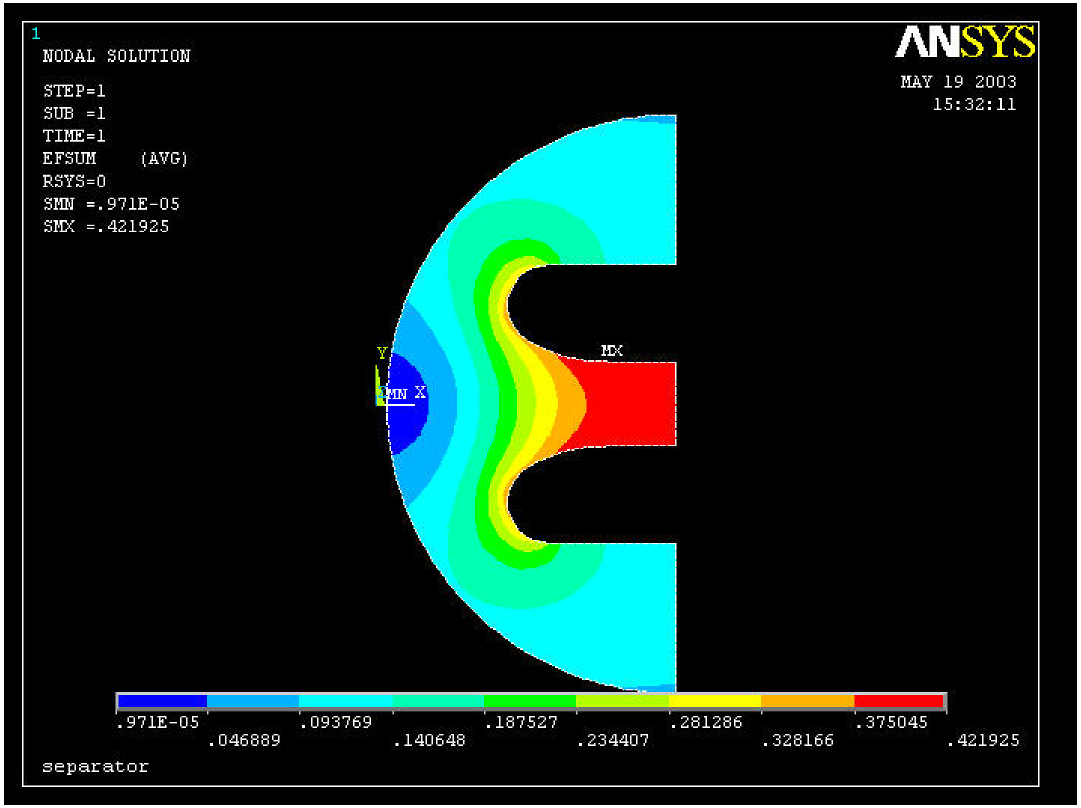
| Voltage [kV] | 120 | 150 | 240 | 300 |
|---|---|---|---|---|
| Field [kV/cm] | 95 | 89 | 80 | 75 |

| Site | polarity | spark rate [sparks/day/separator] |
|---|---|---|
| CESR (H) | bipolar | 0.05 |
| FNAL | bipolar | 0.002 |
| CERN (H) | positive | 0.02 |
| CERN (H) | negative | 100 |
| CERN (V) | bipolar | 0.01 |
| KEK | bipolar | < .03 |




Our goal is close to the edge of performance

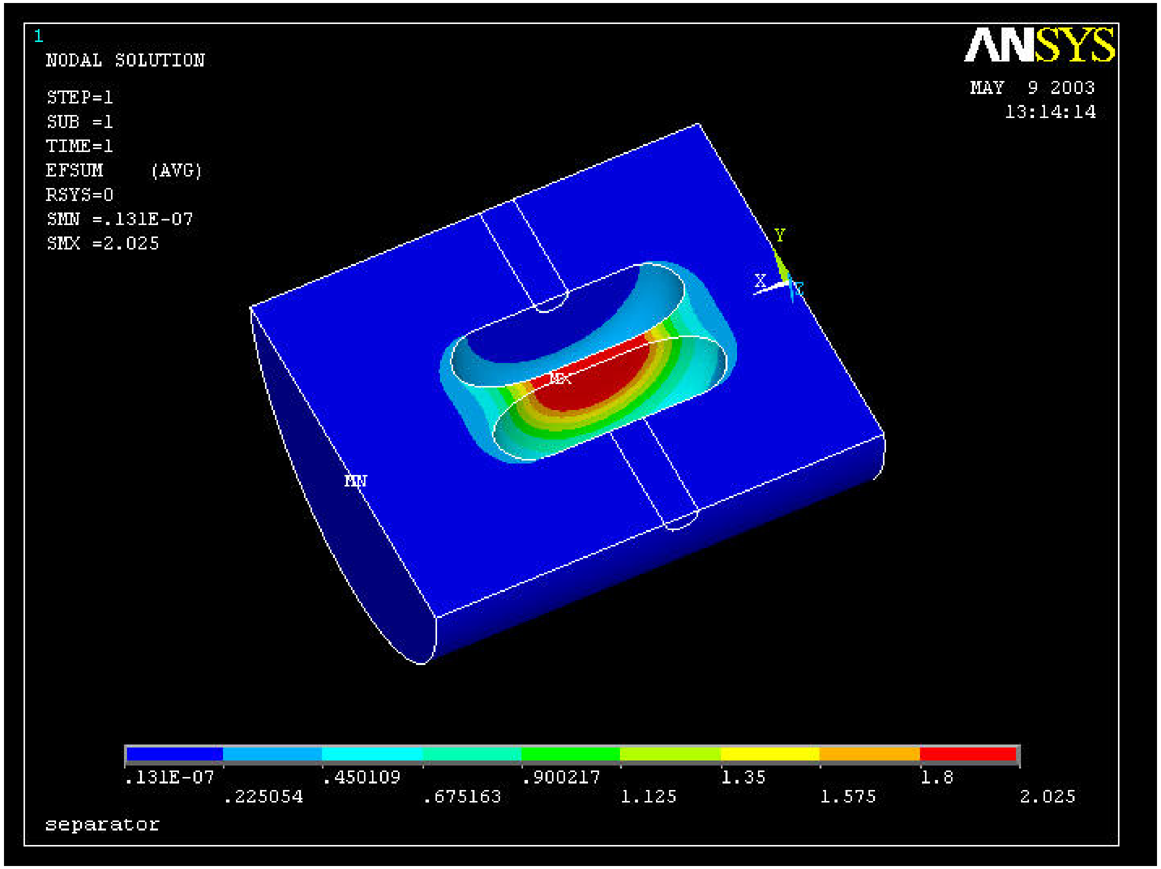
# Field distribution in operating separator configuration.




There are hot spots on the electrode edges with field strength about 70-80% of nominal field in the gap. The tank diameter is small.

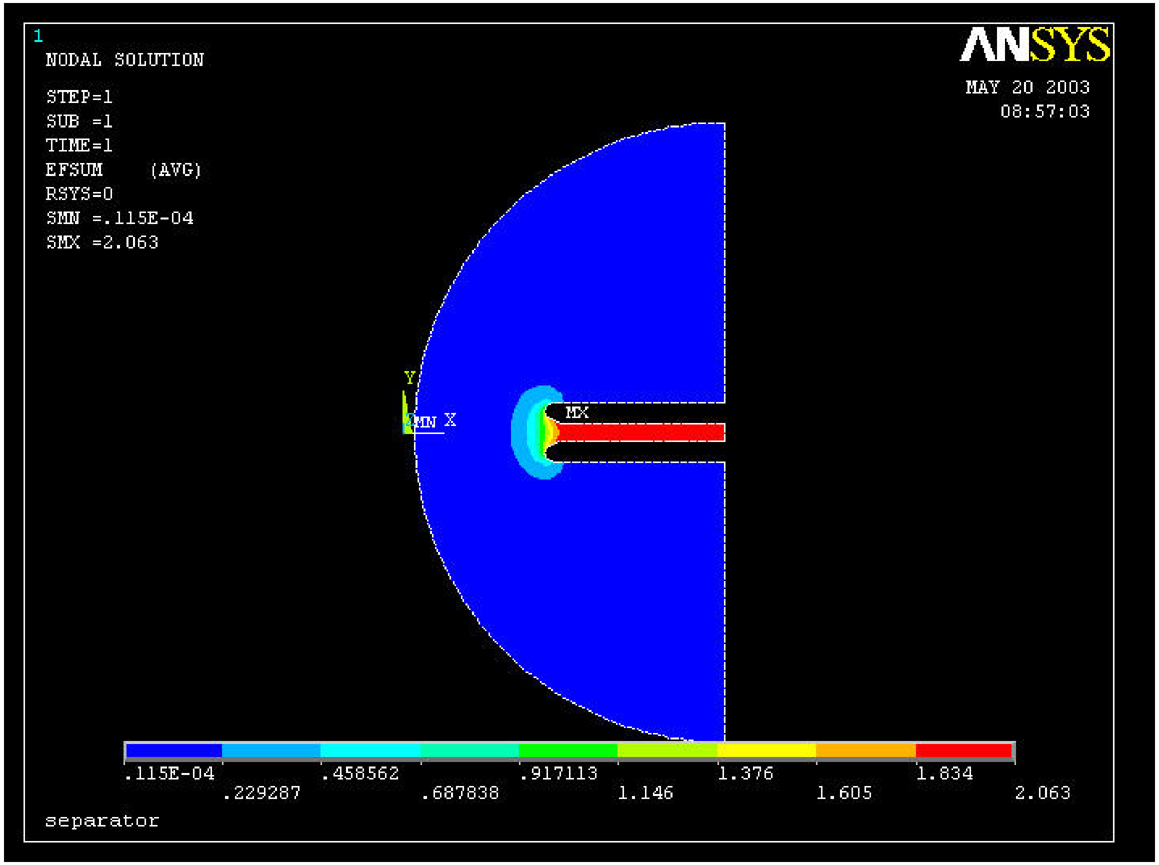
# Field distribution in test separator configuration

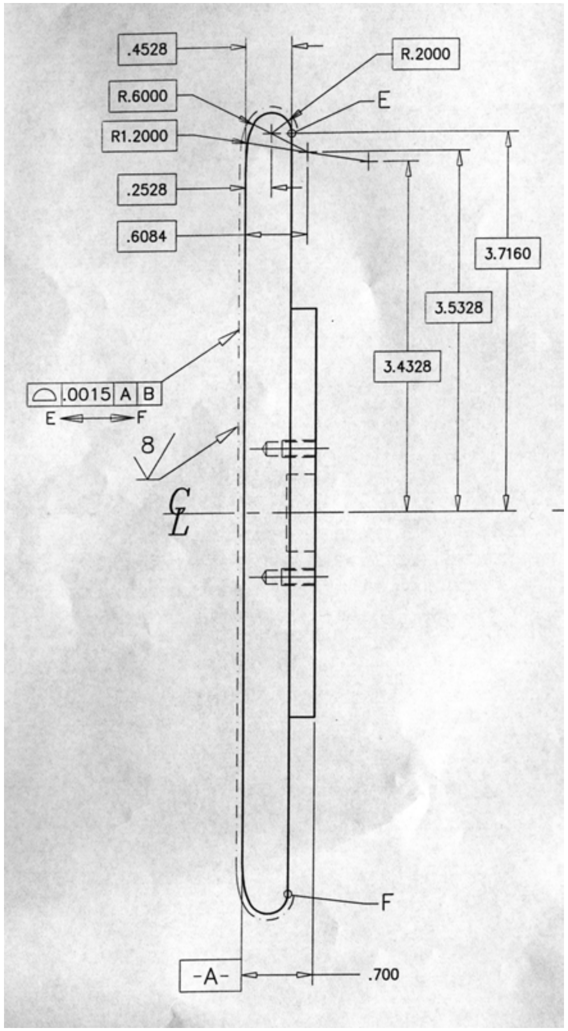
For 1 cm gap (we have to use this gap) and the existing thick test electrodes




the field distribution is pretty good, but effective area is reduced

# Optimal electrodes  for 1 cm gap




We can increase the effective area of electrodes using more optimal  shape. It would bring more reliable results.

# Electrodes materials.

**Stainless steel.** First experiment should be done with stainless steel, which is used in operating separators.

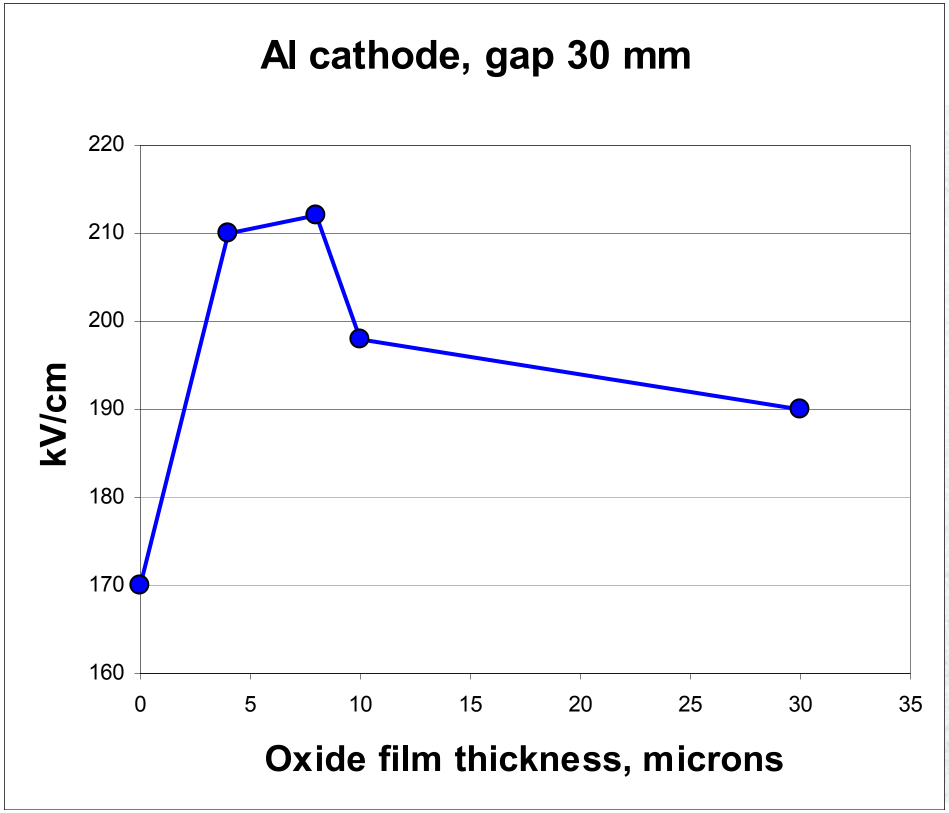
**Aluminum.** The main goal of the experiments is to check semiconducting glass coating. Anodic oxidation of aluminum cathodes can increase high voltage holdoff capability. Though aluminum cathodes probably cannot be used because of changing polarity in Tev separators, it might be interesting to test them. Usually pure aluminum or Peraluman PRE-30 is used. The electrodes are mechanically polished; the final polishing step is made with velvet pad. The electrodes are oxidized in a sulphuric acid bath (concentration 20% by weight) at room temperature ($\approx$20°C), and then sealed off in a boiling distilled water bath for 1 hour. The thickness of oxide is varied by varying the oxidation time. An optimum value of oxide thickness is found to be 5 microns

**Pure titanium** electrodes are used in TRISTAN separators because of its excellent high voltage characteristic (as the designers believe) and mechanical properties. Operating voltage is 240 kV, gap is 8 cm (i.e. 30 kV/cm), very low spark rate. It would be interesting to test titanium electrodes too.

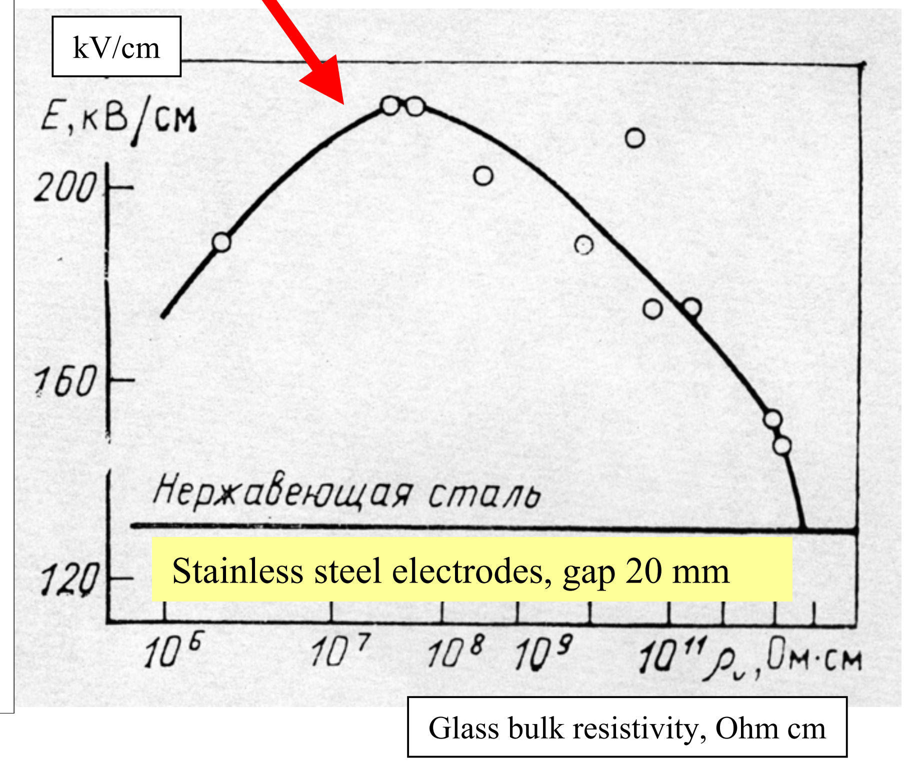
**Oxygen free copper.** Six electrodes (optimal shape for 1 cm gap) are expected to be ready by the end of September to study mechanical and chemical copper surface treatment (for NLC project) .

# Coating

"Dielectric-coated cathodes show up to 70% increase in voltage."




Glass cathode, SS anode, gap 20mm




Thin films

Glass, thickness 15 mm.

# Semiconducting glass.

Two cases of experiments with semiconducting glasses for separators have been found in literature. In ITEP (Russia) an oxidized glass (prepared in house with special thermal treatment, no details) with bulk resistivity of $10^{10}$ Ohm cm at room temperature has been used as cathode. The achieved voltage was 600 kV in 4 cm gap. But this separator worked at partial pressure of 0.1 Pa (Helium) and spark rate was 1 spark/hour (1969).

In CERN experiments with glasses (industrial samples) the best result was 470 kV in 5 cm gap. The optimum bulk resistivity has been found almost the same $10^{10}$-$10^{12}$ Ohm cm. There is no data on spark rate, but the conclusion made by CERN people was “no sparking improvement was observed” (1964).

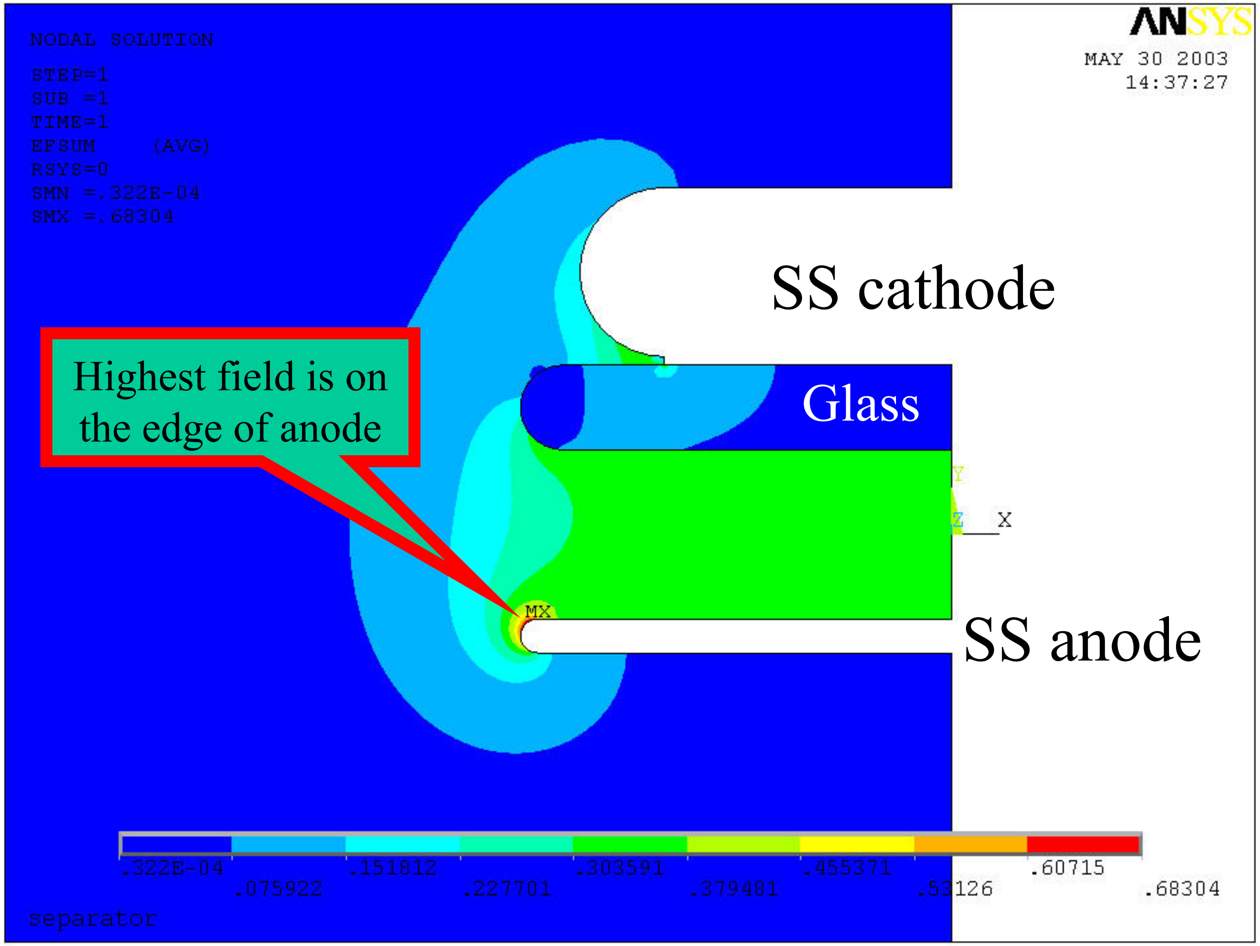
## ITEP separator.

Electrodes 150x32 cm.
Cathode – semiconducting glass (15 mm thickness, bulk resistivity $10^{10}$ Ohm cm)
Anode – stainless steel.
Gap – 4 cm

600 kV. He 0.1 Pa. Sparking rate < 1 spark/hour.

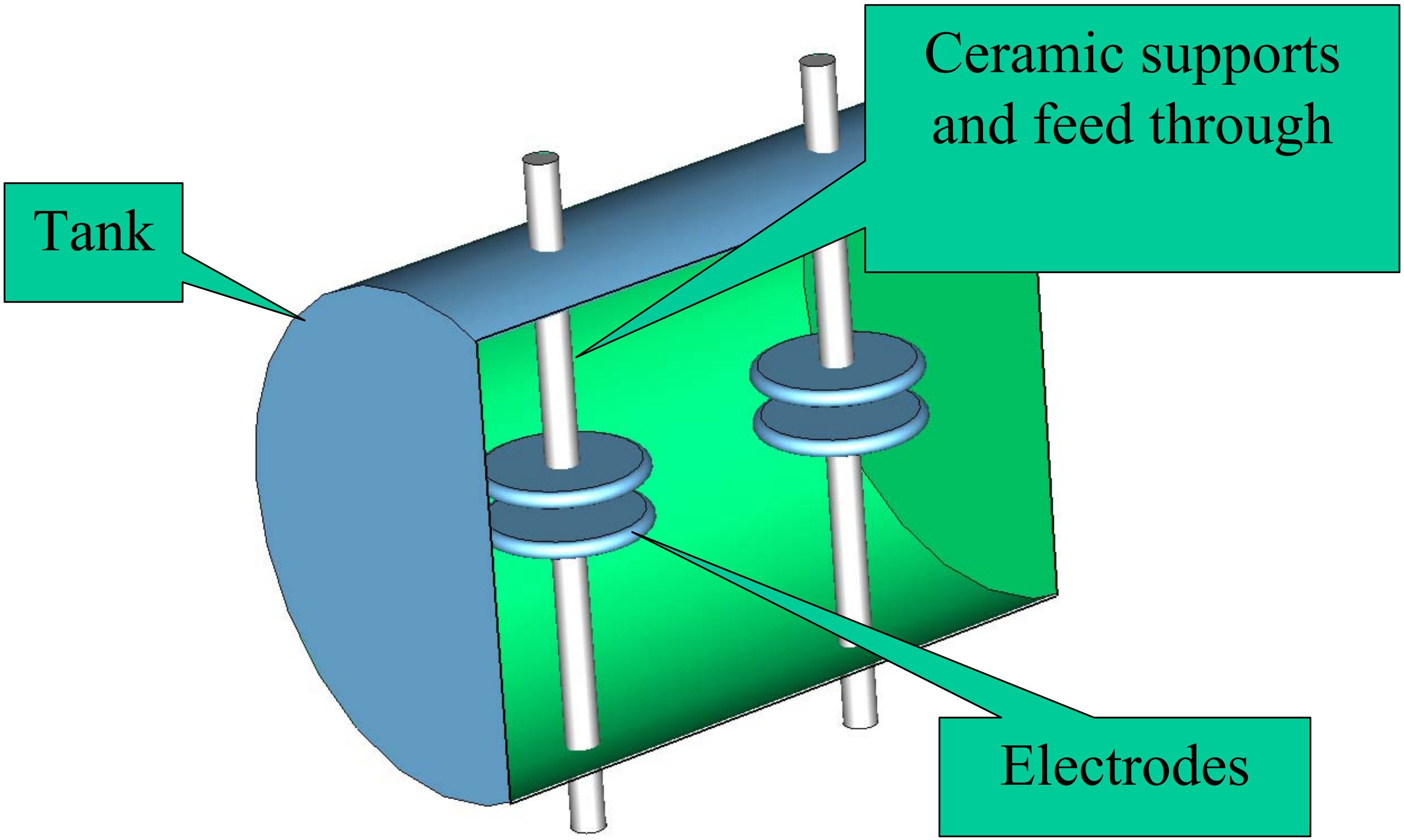
Sparking rate is not impressive

# CERN experiments with glasses

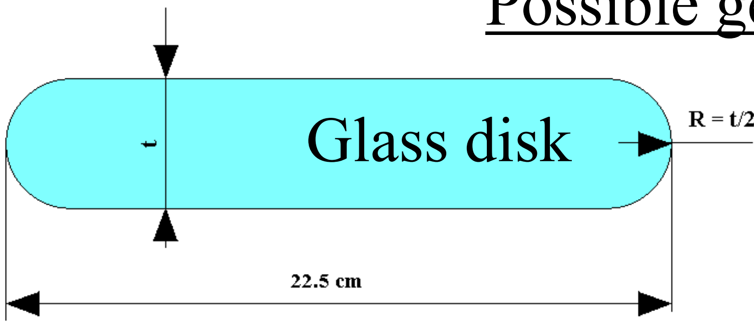



The reason for not promising results may be a wrong anode shape.

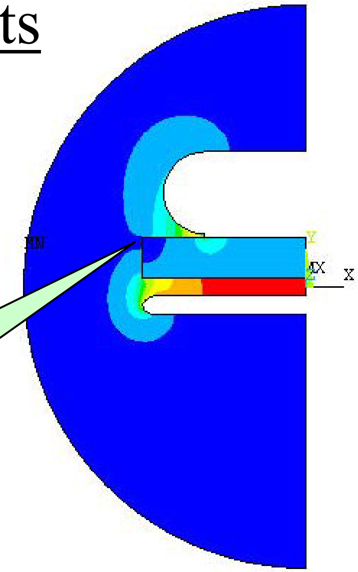
# Sketch of the FNAL test cavity.



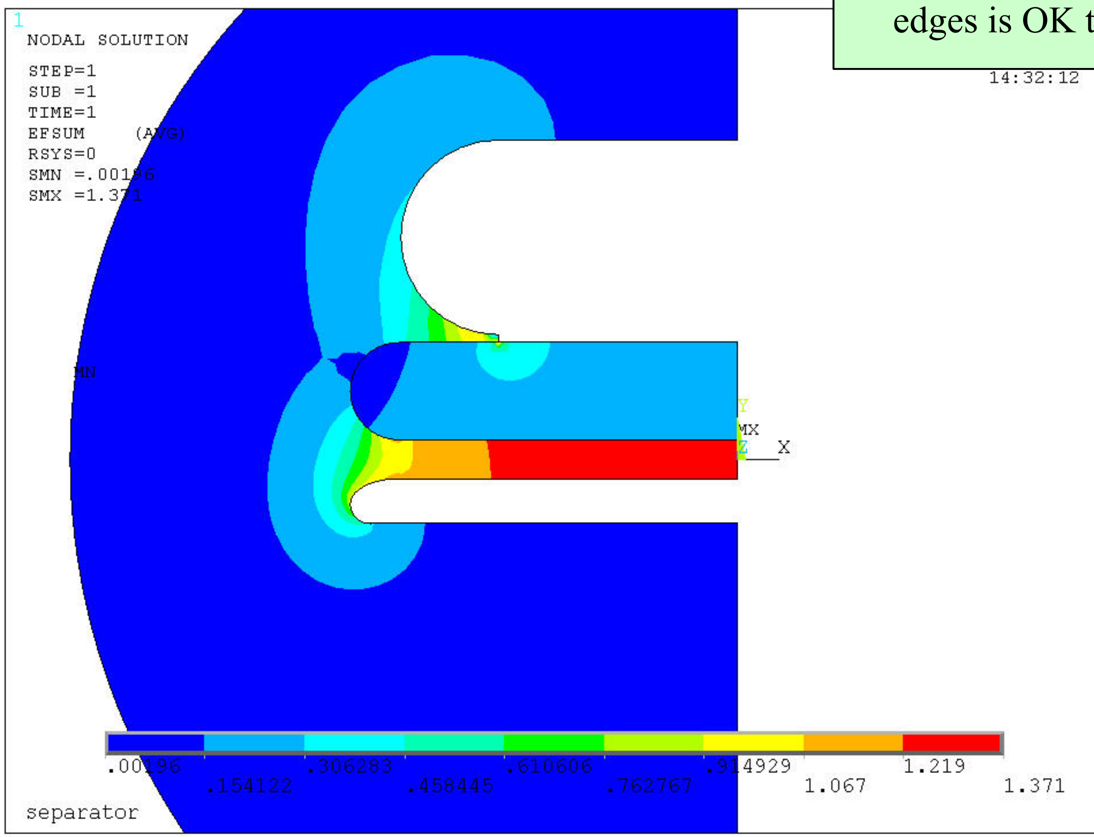
# Possible geometries for our tests




t = 15-35 mm




Glass disk with sharp edges is OK too.




**Pestov's spark counter used :**

**Schott Glass Technologies, Inc**. (Duryea, PA). The glass is marked S8900 and has volume resistivity of $10^{11}$ Ohm cm at room temperature. It has been attached to metal substrate with the use of dry film adhesive, type T100004 (**Sheldahl, Materials Div.,** Northfield, MN).